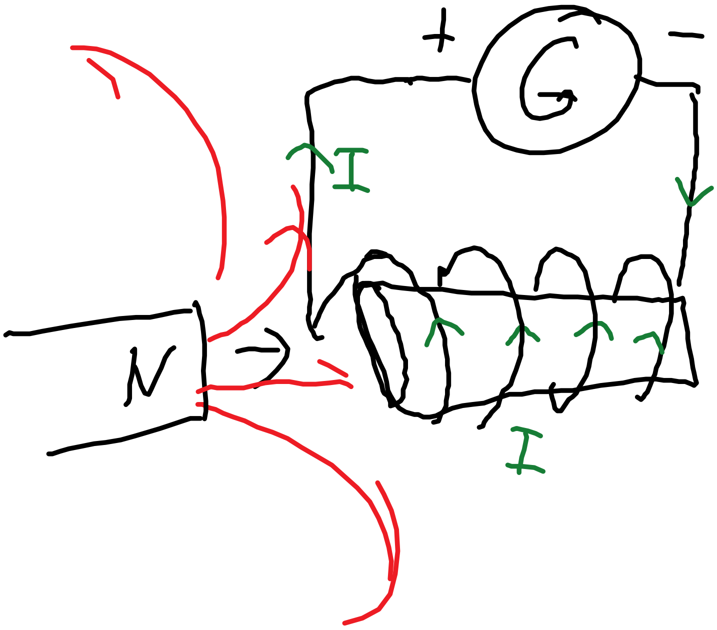
Len's Law of Induction

A solenoid connected to a galvanometer and you insert a magnet.
Predict the size and direction of the current in the galvanometer.



Induced Emf → $$\text{Emf} = -N\frac{\Delta\Phi}{\Delta t}$$ ← opposes the change

$$\Phi = BA$$

↑ flux

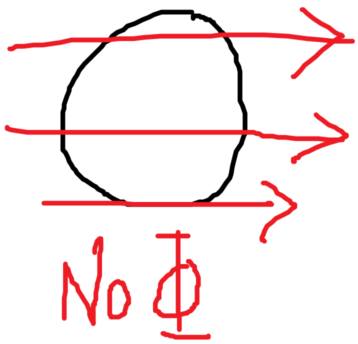
When the magnet enters the coil, it induces a current, I. The direction of the current can be derived 2 ways 1) Right hand rule v,B,F where v is the relative motion of positive charge in the wire, B is the magnetic field perpendicular to the wire and F is the force on the charge in the wire causing current.

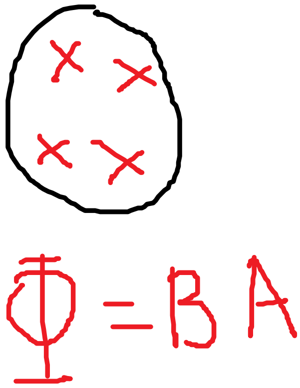
2) The current direction can also be derived by thinking that the current creates a magnetic field opposing the change in flux. eg. originally

you had no field in the solenoid, then you have a field going right, the current will create a field going left.

Flux, Φ, is the magnetic field in an area - perpendicular to the area. units Weber, $Wb=Tm^2$

$\Phi=BA$





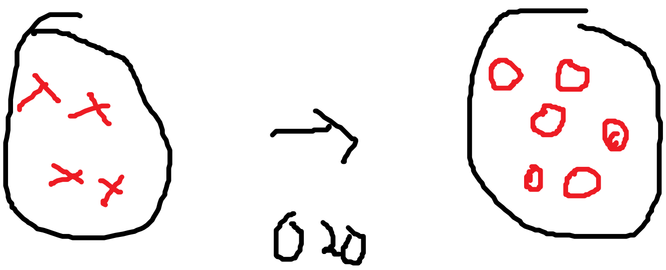
emf is the voltage around the loop, in V.

N is the number of loops of the coil.

emf = $-N\Delta\Phi/\Delta t$

it is determined by the rate of change in the flux.

eg. a 5.0 cm radius circular set of 50 loops are in a 0.14T magnetic field. The field changes to 0.23T the other way. If the resistance in the coil is 4.0 ohms, what is the size and direction of the current in the loop if the change takes 0.20s?



The induced current opposes the change in flux, so it will create a magnetic field into the page to counter the change from in to out. A clockwise current creates a magnetic field into the page.

The induced current is clockwise.

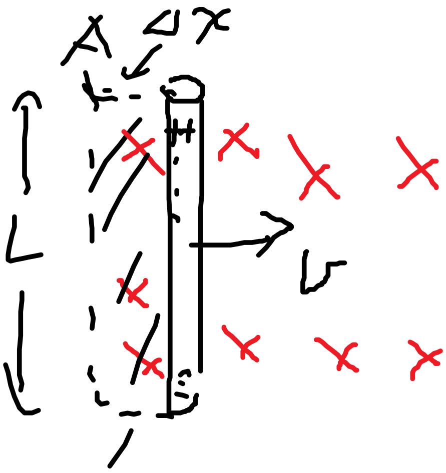
direction

emf = - NA(Bf-Bi)/t

emf = 50x(3.14159x0.05x0.05)x(0.23+0.14)/0.2
=0.72649 =0.73V
I=V/R = 0.72649/4=0.18162 = **0.18A**

p566Q1-13 odds

Moving conductor:



RHR

$A = \Delta x L$

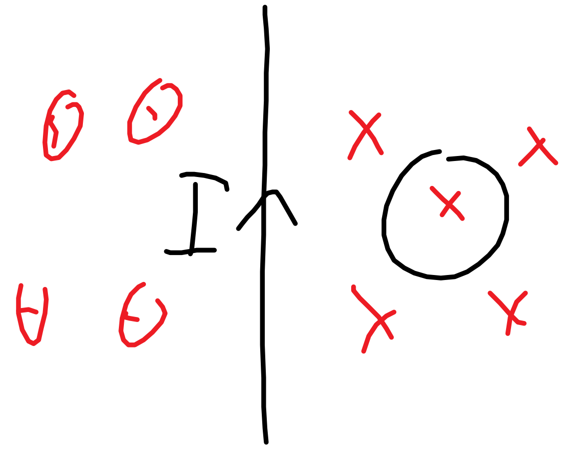
$\Delta\Phi = \Delta x L B$

The charges in the conductor will be pushed to opposite sides.

$$Emf = -N\frac{\Delta\Phi}{\Delta t} = BL\frac{\Delta x}{\Delta t} =$$

$$\text{Emf} = BLv$$

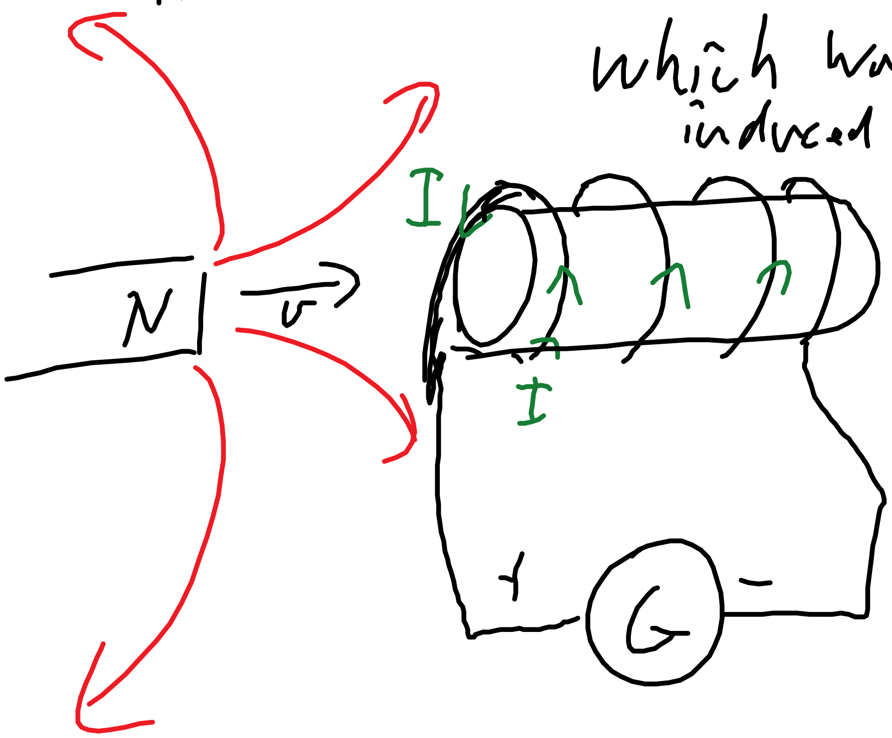
Q5



Q

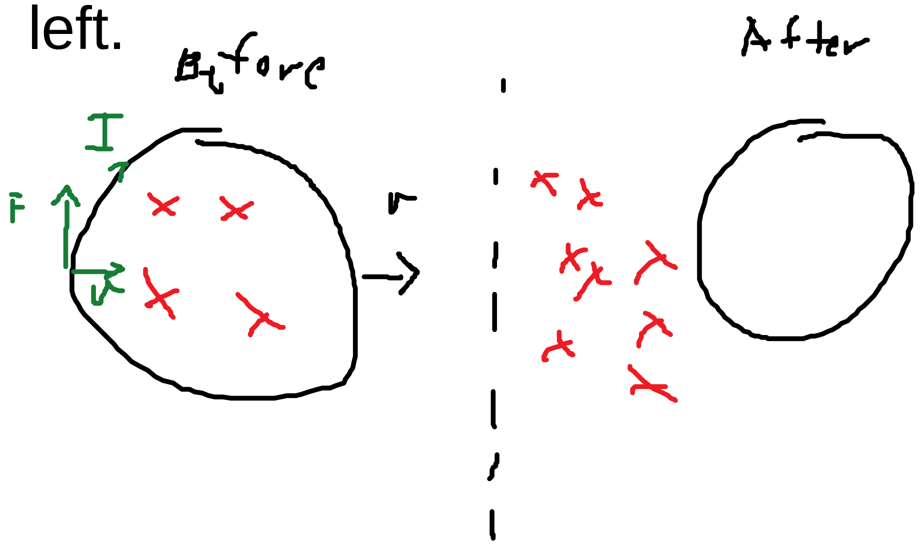
Block 2-3

which way does the induced current flow?



We can predict the direction of the current in the solenoid 2 ways:

1. Right hand rule, RHR, thumb is the velocity of the positive charge, index finger is magnetic field and middle finger is force on the charge (causing current) we see the direction of current shown in the diagram.
2. The second way to derive the direction is to use the principle that the induced current opposes the change in magnetic field inside the loops. So, when you put the North end of a magnet in, it puts a magnetic field left to right, so the induced current creates a magnetic field right to left.



the induced current opposes the change from field into the page to no field, so it will be clockwise, creating a field into the page.

What factors will influence the amount of current?

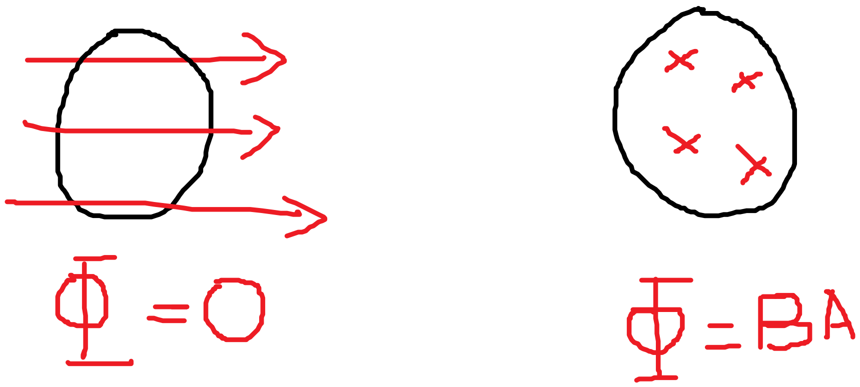
how fast is the change

magnetic field
Area in the magnetic field
number of loops

Lens' Law

Flux, Φ, is the product of the magnetic field and the area in the field.

$\Phi = BA$ in Webers, $Wb = Tm^2$

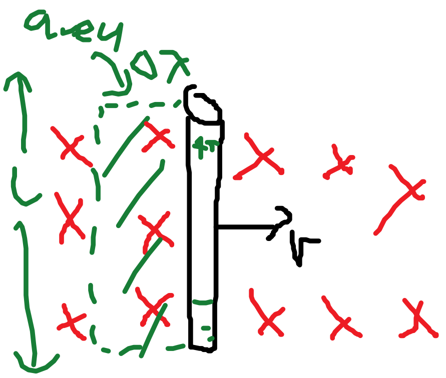


emf induced around the loop equals the number of loops x the rate of change in the flux.

$emf = -N\Delta\Phi/\Delta t$

N is the number of loops
the negative sign tells you that the emf creases a current opposing the change in flux.

If you have a moving conductor, and emf is induced between the ends.



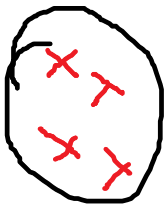
$$Emf = -N\frac{\Delta\Phi}{\Delta t}$$

$$Emf = \frac{B\Delta A}{\Delta t} = BL\frac{\Delta x}{\Delta t}$$

v

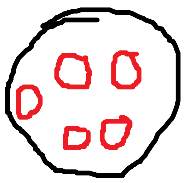
$$\boxed{Emf = BLv}$$

eg. 1. A circular loop with radius 5.0 cm is in a 0.23 T magnetic field going into the page.



a) what is the flux in the loop?

the magnetic field is steadily changed to 0.14T out of the page over 0.20s.



b) what is the direction of the induced current in the loop?
c) what is the emf around the loop?
d) if the resistance of the loops is 4.0 ohms, what is the current in the loop?

2. An aluminum airplane moving at 50.0 m/s

through the Earth's magnetic field of 1.5 x 10^{-4}T, with a wingspan of 10.0m. What is the potential difference across the wings? If it is flying north, near the North Pole, which wing is positive, East or West?

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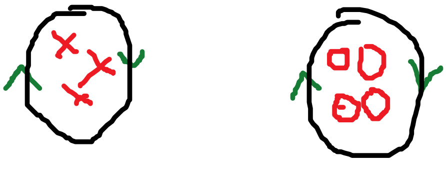
eg. 1. A circular loop with radius 5.0 cm is in a 0.23 T magnetic field going into the page.

a) what is the flux in the loop?

Φ=BA = 0.23Tx(pix(0.05m)^2) = 1.8×10^{-3}Wb

the magnetic field is steadily changed to 0.14T out of the page over 0.20s.



a) what is the direction of the induced current in the loop?

Since the field changes from into the page to out of the page, the current will create a magnetic field opposing the change.
The current creates a magnetic field into the page, so the current must be clockwise.

a) what is the emf around the loop?

emf = $-N\Delta\Phi/\Delta t$ = N(A)(Bf-Bi)/t
= 1(pix0.05^2)(0.14-(-0.23))/0.2s
= 1.5×10^{-2}V

a) if the resistance of the loops is 4.0 ohms, what is the current in the loop?

I=V/R = 0.015/4=0.0038 A

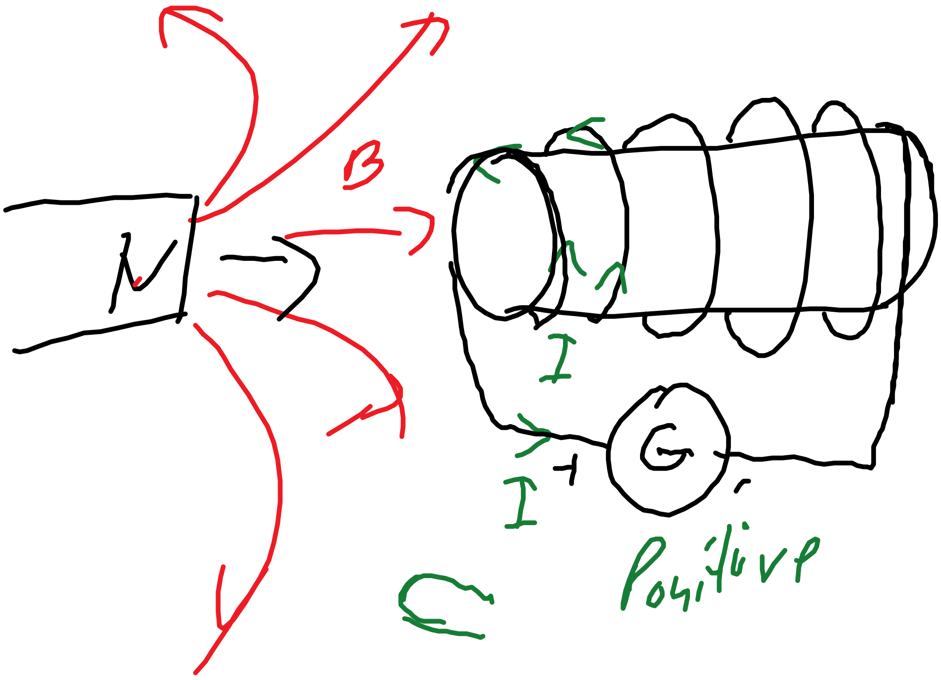
1. An aluminum airplane moving at 50.0 m/s through the Earth's magnetic field of 1.5 x 10^{-4}T, with a wingspan of 10.0m. What is the potential difference across the wings? If it is flying north, near the North Pole, which wing is positive, East or West?

Block 2-2

Magnetic Induction and Lenz's Law

Let's look at our apparatus (see in the lab Tuesday, Labbook p109-114)
Galvanometer connected to a solenoid and you

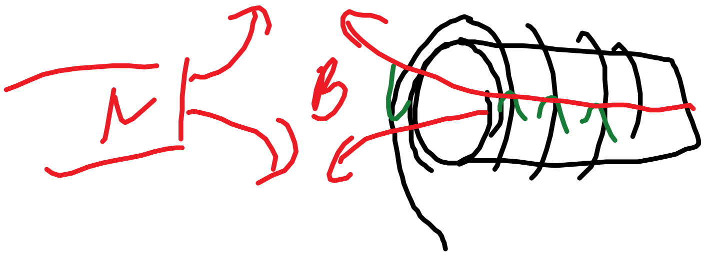
Galvanometer connected to a solenoid and you insert a magnet. What is the size and direction of the current induced in the solenoid?

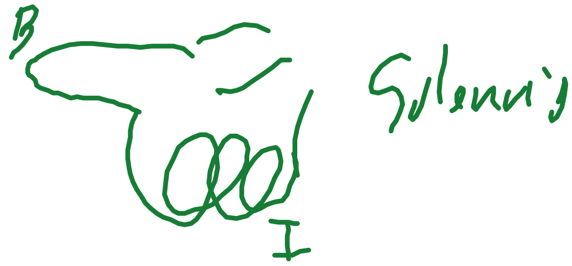


We can predict the direction of the current in the solenoid by

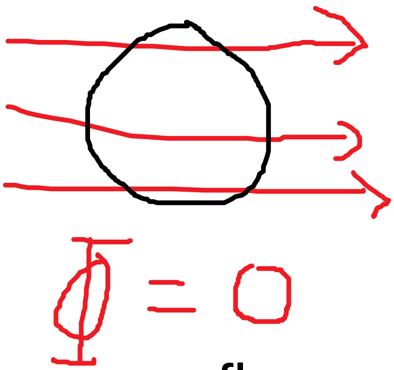
1. Use the right hand rule for moving charges. The positive charges in the wire are moving left relative to the magnet. The field on top has an upward component resulting in a force into the page on the charge. The field on the bottom has a downward component, resulting in a force out of the page. This results in a positive current through the galvanometer.
2. The induced current creates a magnetic field opposing the change.
   The field in the solenoid changes from "no field" to field "left to right". The current in the solenoid is such to create a field right to left.

solenoid is such to create a field right to left.





Define the Magnetic flux, Φ, is the product of the magnetic field and the area crossed by the field.



no flux

flux = BA (max)

flux is measured in Webers, $Wb = Tm^2$

emf is the voltage induced around the conducting loop, in V.

opposes the change

$$emf = -N\Delta\Phi/\Delta t$$

N is the number of loops of wire.

$\Delta\Phi/\Delta t$ is the rate of change in flux - either the magnetic field or the area in the field change.

eg. 1). 20 circular loops with radius 5.0 cm are in a 0.23 T magnetic field going into the page.

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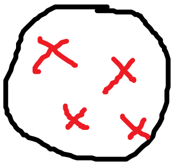
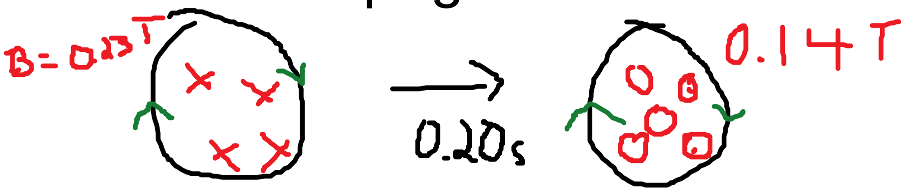


a) what is the flux in the loop?

$\Phi = BA = 0.23 \times 3.14159 \times 0.05 \times 0.05 = 0.0018\,Wb$

the magnetic field is steadily changed to 0.14T out of the page over 0.20s.



b) what is the direction of the induced current in the loop?

The magnetic field changes from into to out of the page. The induced current creates a field opposing the change, so it creates a field into the page. Therefore the current is clockwise.

c) what is the emf around the loop?

$emf = -N\Delta\Phi/\Delta t = N \times A \times (B_f - B_i)/t$

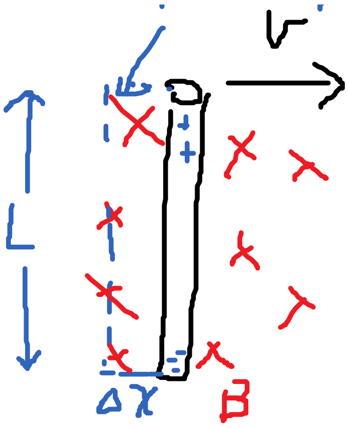
$20 \times (3.14159 \times 0.05 \times 0.05) \times (0.14-(-0.23))/0.2 =$

$0.2906 = 0.29\,V$

d) if the resistance of the loops is 4.0 ohms, what is the current in the loop?

$I = V/R = 0.2906/4 = 0.0727 = 0.073\,A$

What about a moving conductor in a magnetic field? Area Swept out = $L\Delta x$



using our right hand rule for moving charges, we see that the positive charges in the conductor are going to experience a force up.
Since there is a build up of charge, there is a potential difference, emf, between the ends.

$emf=-N\Delta\Phi/\Delta t = BA/t = BL\Delta x/\Delta t$

$emf=BLv$

emf across a moving charge, move at velocity v perpendicular to field, B, with length L perpendicular to both v and B.

eg. An aluminum airplane with wingspan of 10.0 m is moving at 50.0 m/s going North near the North pole. The magnetic field of the Earth is about 1.5×10^{-4}T.

a) what is the charge of the Eastern wingtip?
b) what is the emf between the wingtips?
c) Why is this a problem? How could you fix it?

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Pre read lab Tuesday, p109-114 in the labbook.